IDS Workshop

Precise Orbit Modeling and Precise Orbit Determination

SENTINEL-3A USO OBSERVED USING GNSS MEASUREMENTS

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SOMMAIRE

- INTRODUCTION
- CLOCK OBSERVED USING GPS
- COMPARISON TO DORIS ESTIMATED CLOCK
- USE OF GPS OBSERVED CLOCK IN DORIS COMPUTATION

INTRODUCTION

Sentinel3A:

- Launched on the 16th of February 2016
- On-board Ultra Stable Oscillator (USO) used by both DORIS and GNSS receiver
- Low Earth orbiter -> passes through the South Atlantic Anomaly (SAA, a region with higher level of radiation)

Clock computation :

- GPS system : enough measurements at each epoch to estimate the on-board clock
- DORIS system : on-board clock estimated by a 3rd order polynomial, using master beacon measurements (5 stations), over 9 days

SAA effects :

- USO performances is degraded when passing through SAA : fast variation of frequency
- On Sentinel3A : degradation is not obvious when studying global metrics (RMS residuals over a cycle, …) BUT a close up on the few DORIS passes over SAA shows that the DORIS USO is indeed perturbed.

Data used :

- From cycle 2 to cycle 10 (i.e. from the 21st of March, 2016 to the 11th of June, 2016)

GPS CLOCK : RECONSTRUCTION OF A CONTINUOUS CLOCK

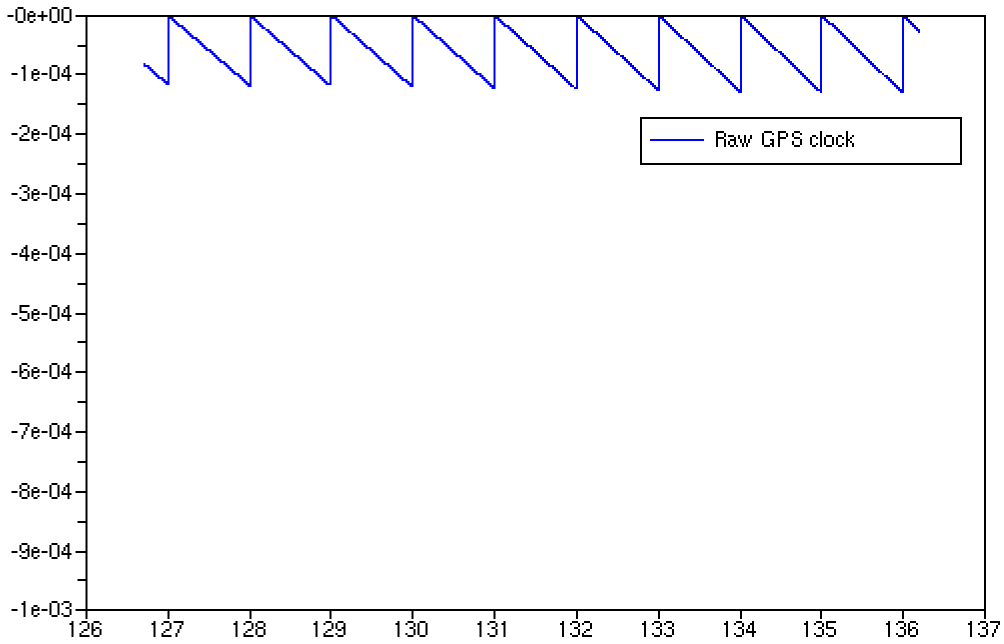
Use of daily rinex files : daily clock bias reset to stay close to GPS reference time (ground segment processing)

Reconstruction of GPS clock using frequency information : clock increments

1. Measurem
   - a 1st deg … to the problem
   - gaps (pea … lynomial
   - OK for ga

2. Reconstru

Clock (s)

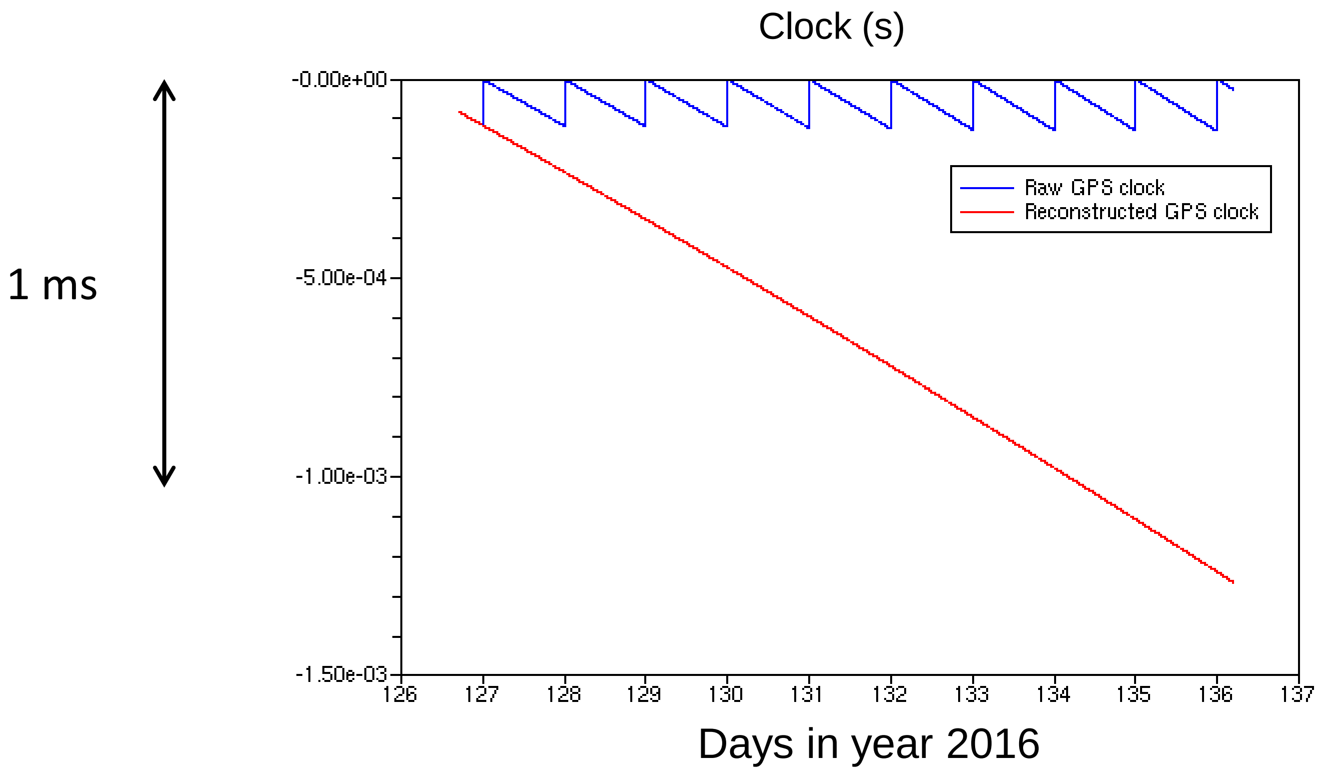


Days in year 2016

(data from cycle 7)

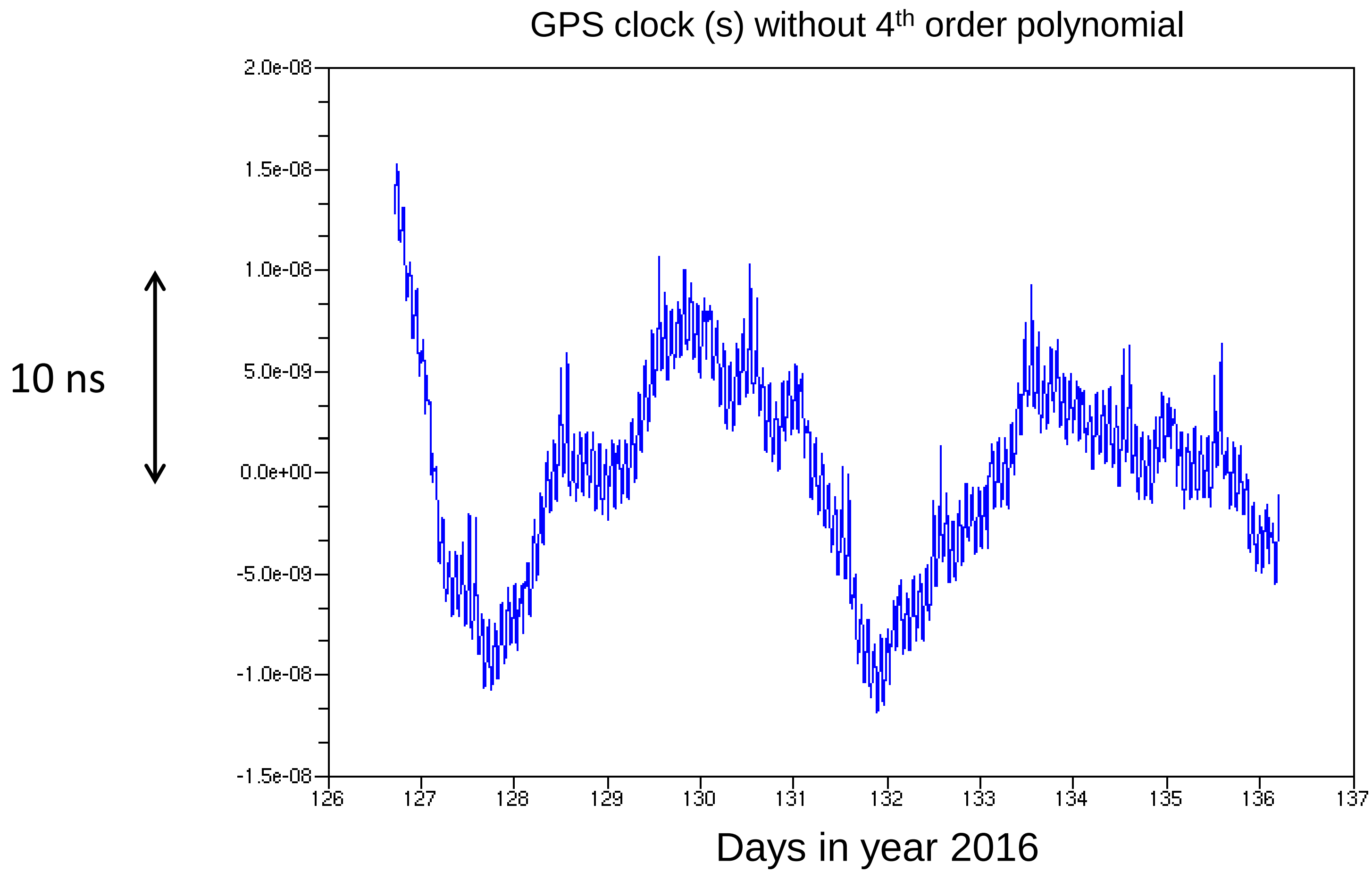
GPS CLOCK : RECONSTRUCTION OF A CONTINUOUS CLOCK

Continuous GPS clock (cycle 7) : polynomial behaviour



GPS CLOCK : HIGH FREQUENCY VARIATIONS

Continuous GPS clock without 4th order polynomial (cycle 7)



GPS CLOCK :
HIGH FREQUENCY VARIATIONS : RELATIVITY

Continuous GPS clock without 4th order polynomial (cycle 7) :
relativistic effects

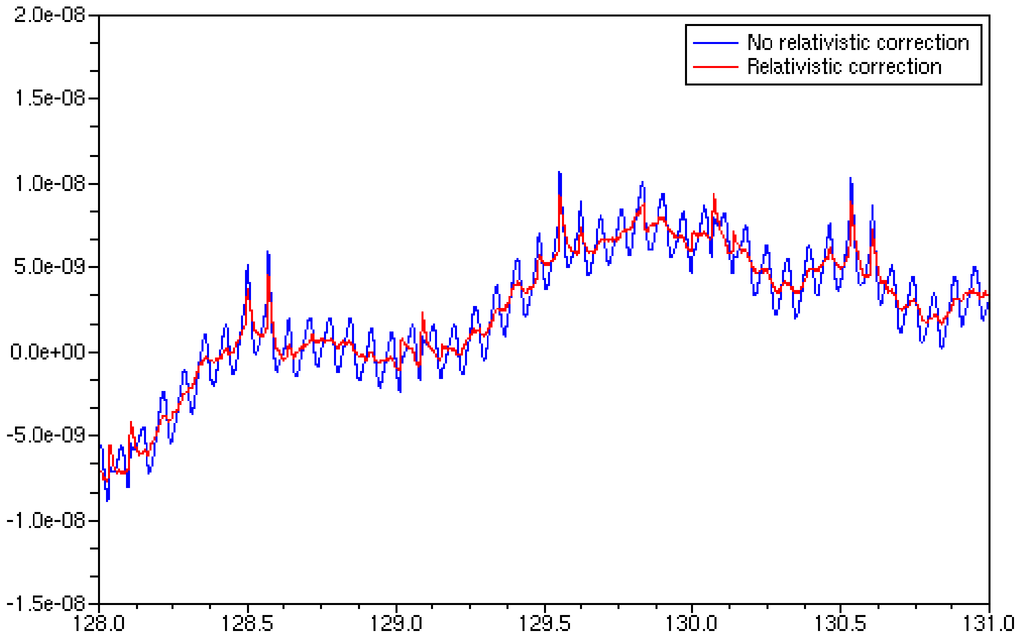
No relativistic correction on Sentinel3A receiver in our software

The proper correction is added post-processing (red curve)
→ much smoother clock ….
… except for systematic spikes

Relativistic correction
(gravity field up to J2)

$$\tau_s = \int \frac{\Delta f}{f} dt = \int \left[-\frac{GM}{c^2 r} + \frac{GMJ_2}{c^2 r} \left(\frac{a_1}{r} \right)^2 \left(\frac{3z^2}{2r^2} - \frac{1}{2} \right) - \frac{1}{2} \frac{v^2}{c^2} \right] dt$$

GPS clock (s) without 4th order polynomial

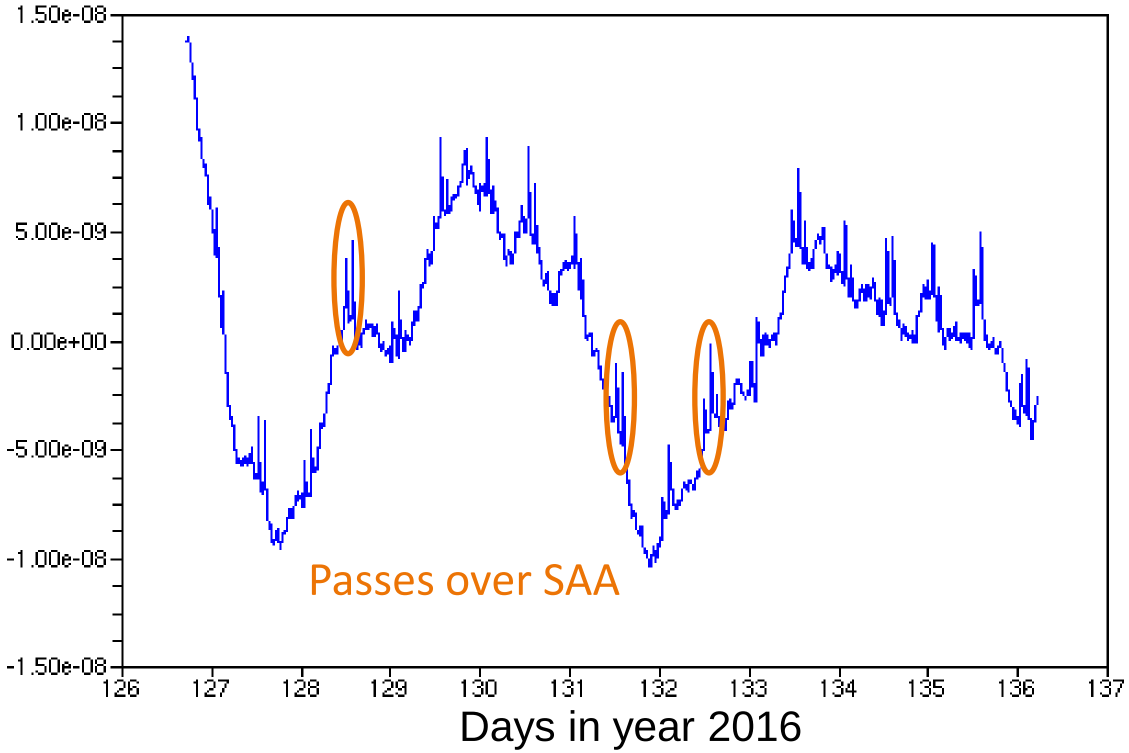


Days in year 2016

GPS CLOCK :
HIGH FREQUENCY VARIATIONS : RELATIVITY

Continuous GPS clock (cycle 7) without 4th order polynomial with relativistic correction :

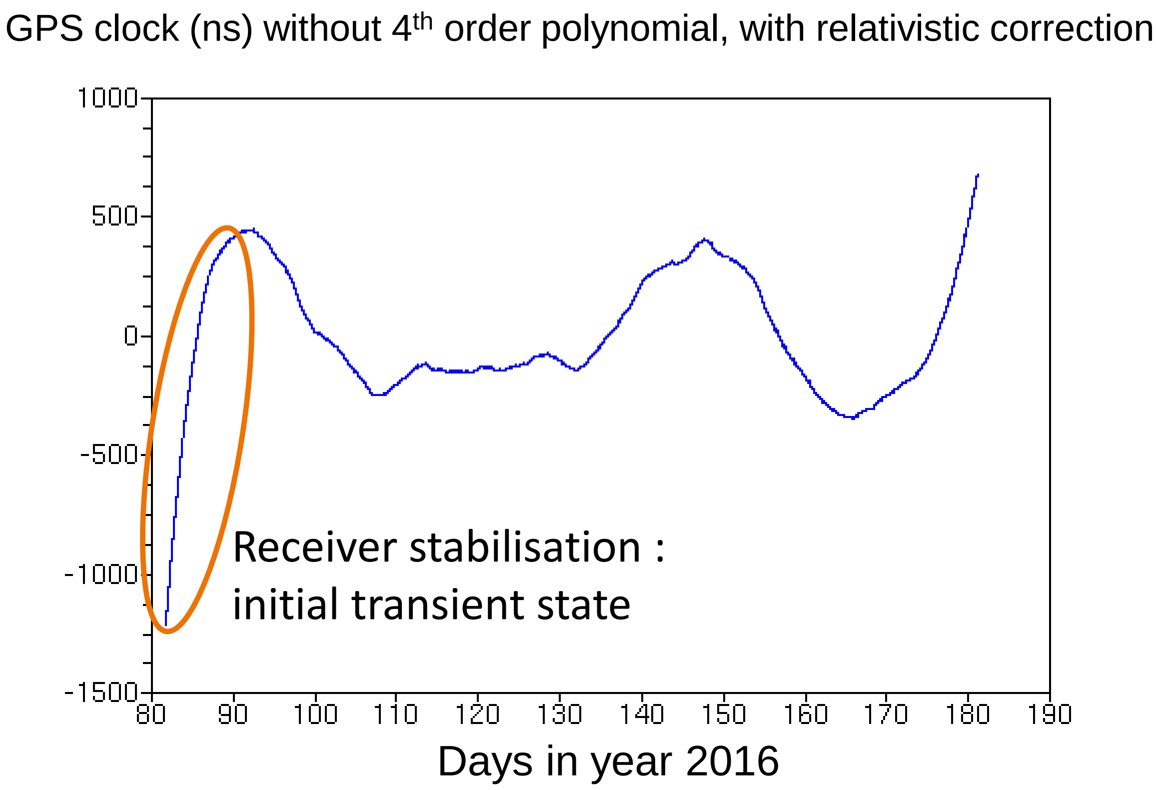
GPS clock (s) without 4th order polynomial, with relativistic correction



- Best observation of OUS
- BUT : no relativistic correction in DORIS computation
- Therefore the GPS clock used in DORIS computation is the one without relativistic correction

GPS CLOCK : OVER 10 CYCLES

Continuous GPS clock (cycles 2 to 12) without 4th order polynomial with relativistic correction :

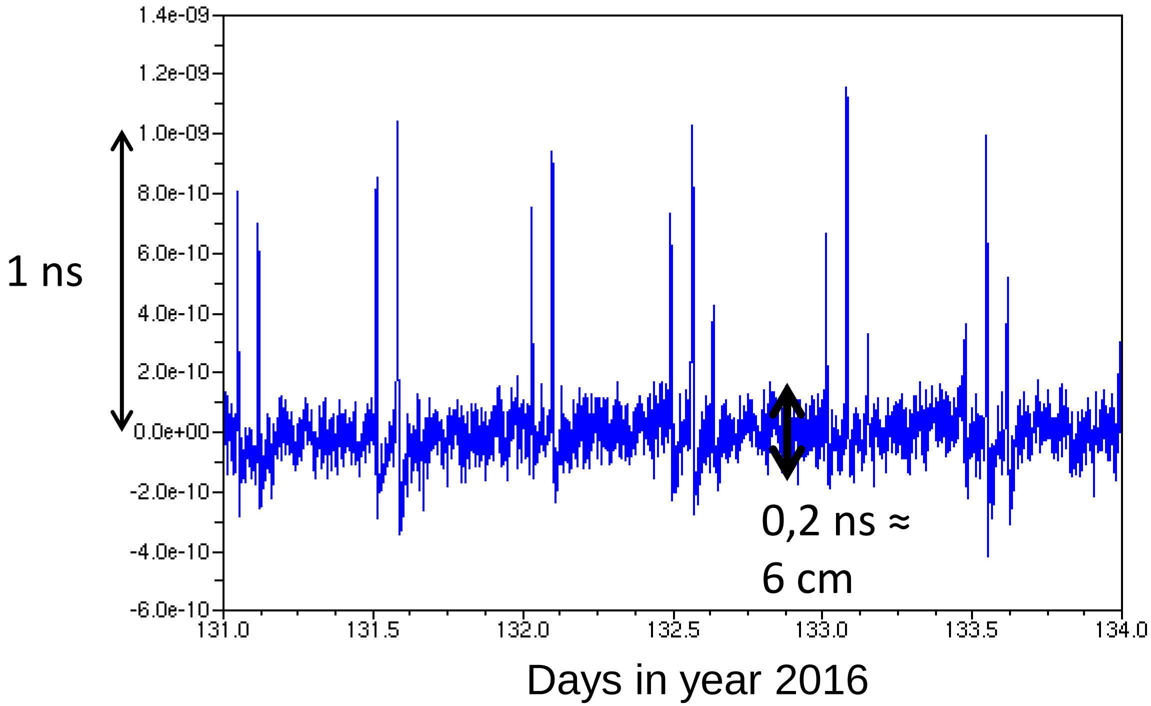


GPS CLOCK :
FREQUENCY NOISE ANALYSIS

Continuous GPS clock (cycle 7) without 4th order polynomial with relativistic correction :

CLOCK VARIATION (120 seconds intervals)

Increments of GPS clock (s) without 4th order polynomial, with relativistic correction



- We need the averaged frequency on a 10s intervals for DORIS : what noise to expect ?
- 6 cm : too large value (cf. F. Mercier, IDS AWG, Delft Netherlands, May 2016)
- But USO frequency is stable
  - Average frequency over 120s is representative of the actual frequency over 10s
  - $6\ cm\ .\frac{10\ s}{120\ s} = 5\ mm$
- DORIS data noise is about 5 mm → GPS clock can be used

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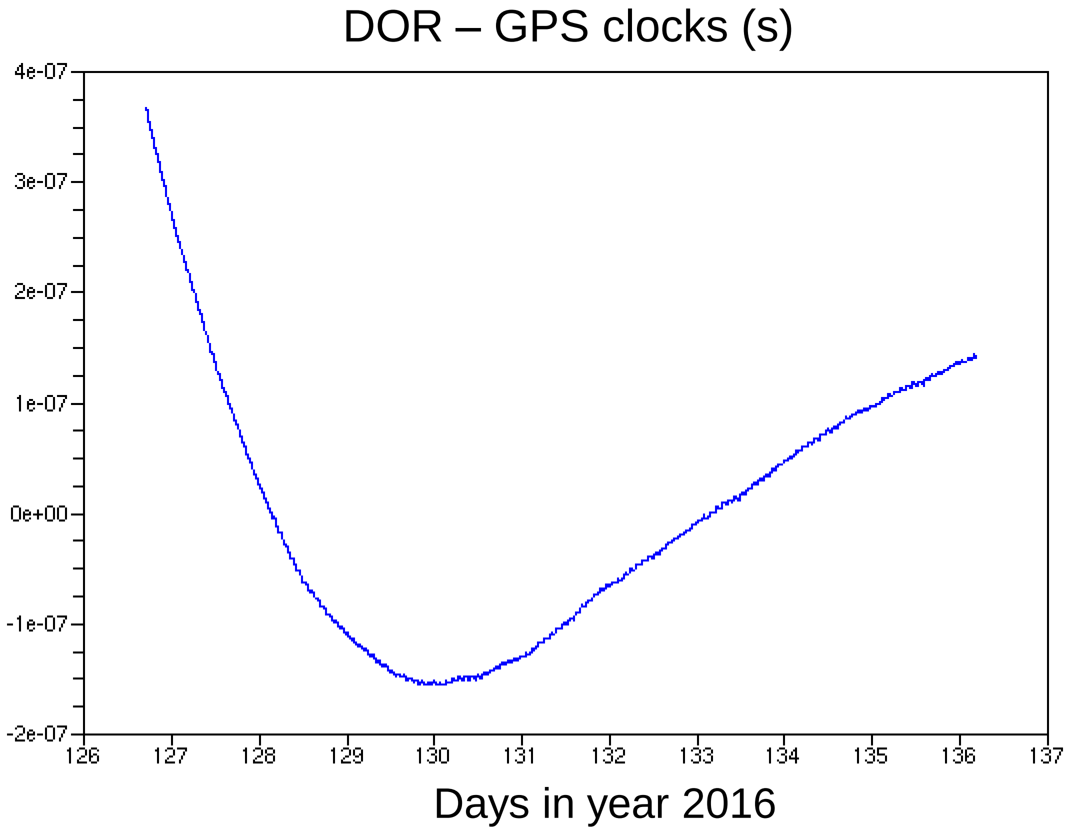
GPS CLOCK : COMPARISON TO DORIS CLOCK

- Estimation of a bias to align GPS clock on the DORIS clock
- DORIS-GPS signal 3rd order polynomial behaviour



GPS CLOCK :
COMPARISON TO DORIS CLOCK

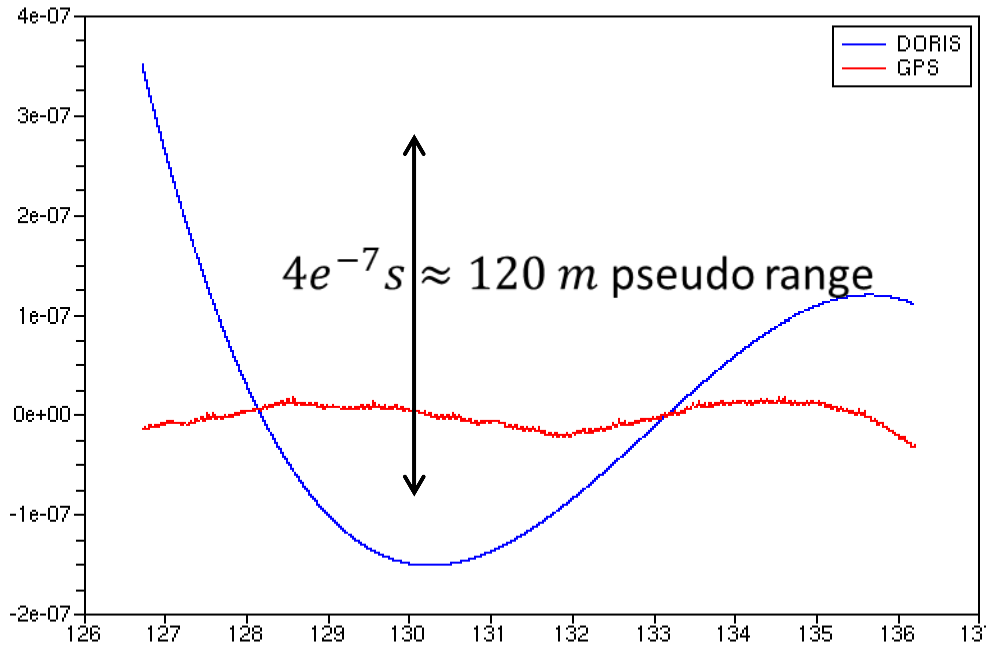
- Estimation of a 3rd degree polynomial on the GPS clock

- DORIS and GPS clocks are different :
  time tagging error ≈ $4e^{-7}s$
  (RMS pseudo range residuals : 2,5 km ≈ $80e^{-7}s$)

- In term of along track error :
  $80e^{-7}s * 7{,}5\ ^{km}/_{s} = 6\ cm$
  $4e^{-7}s * 7{,}5\ ^{km}/_{s} = 0{,}3\ cm$

→ no impact on orbit

Clocks (s) without 3rd order polynomial



Days in year 2016

GPS CLOCK : POLYNOMIAL BEHAVIOUR

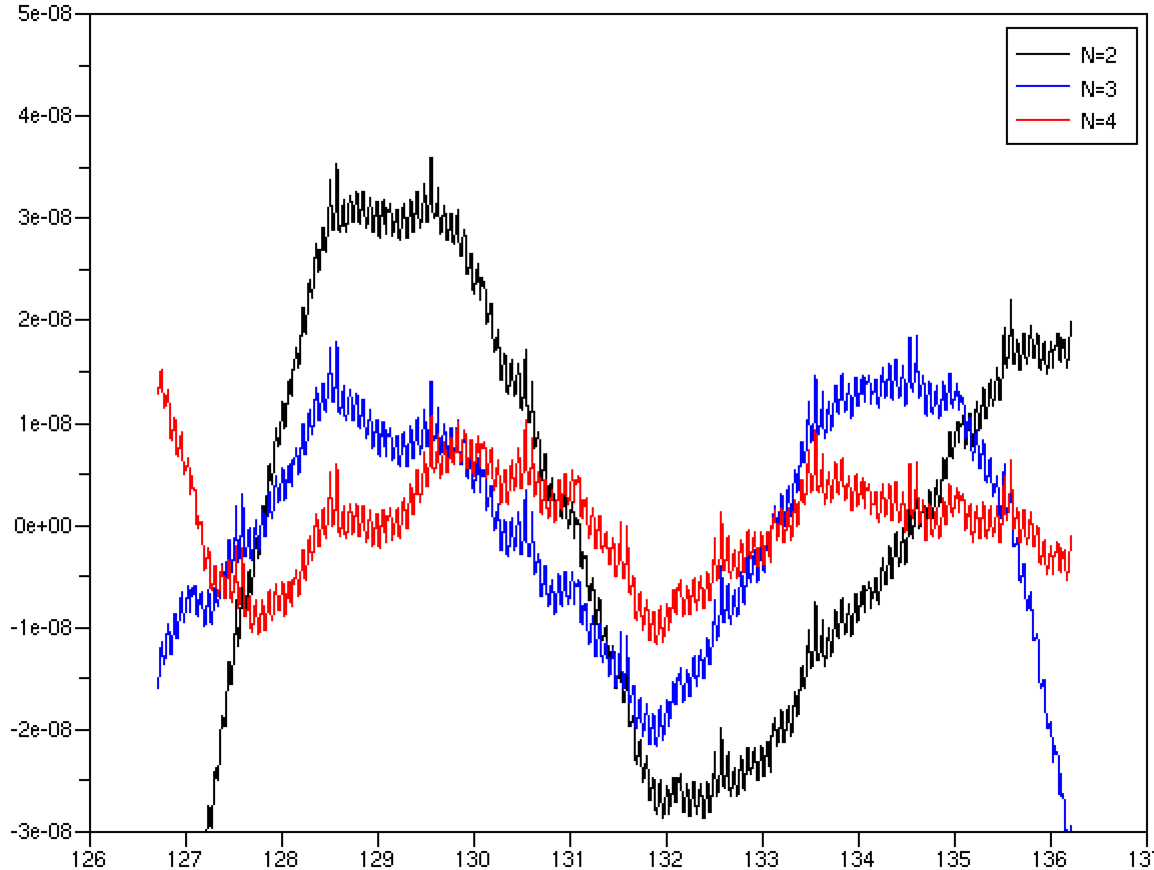
What strategy to perform DORIS time tagging ?

- GPS clock can be well observed
  N=2 : 3rd degree signature left : $6e^{-8}s$

- DORIS time tagging error on the 3rd degree polynomial (previous slide) : $4e^{-7}s$

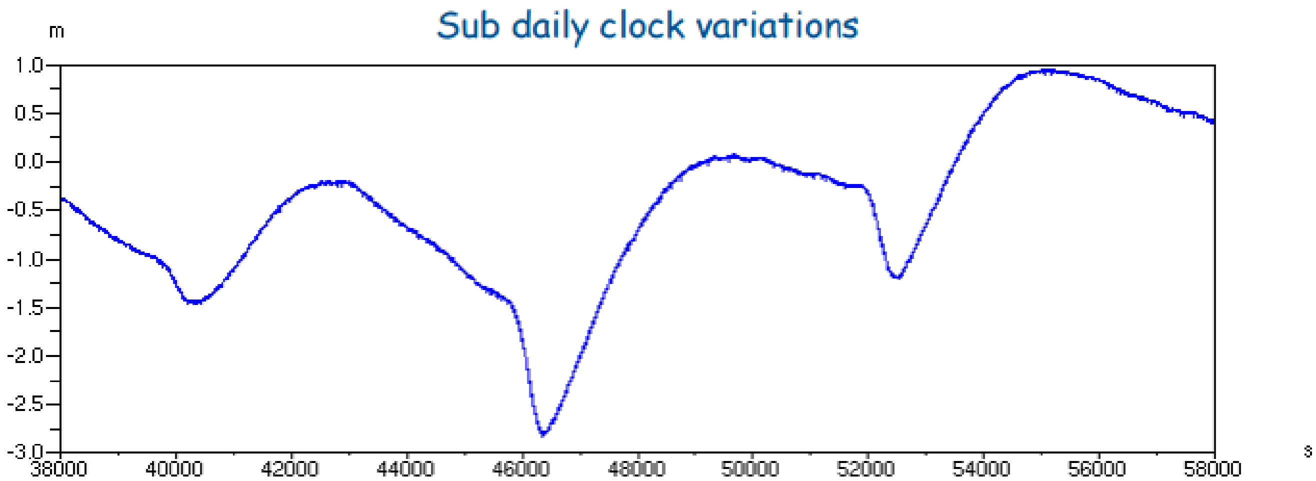
- When performing DORIS time tagging :
  Maybe there is no need to estimate a 3rd degree order polynomial.
  2nd degree polynomial would be enough.

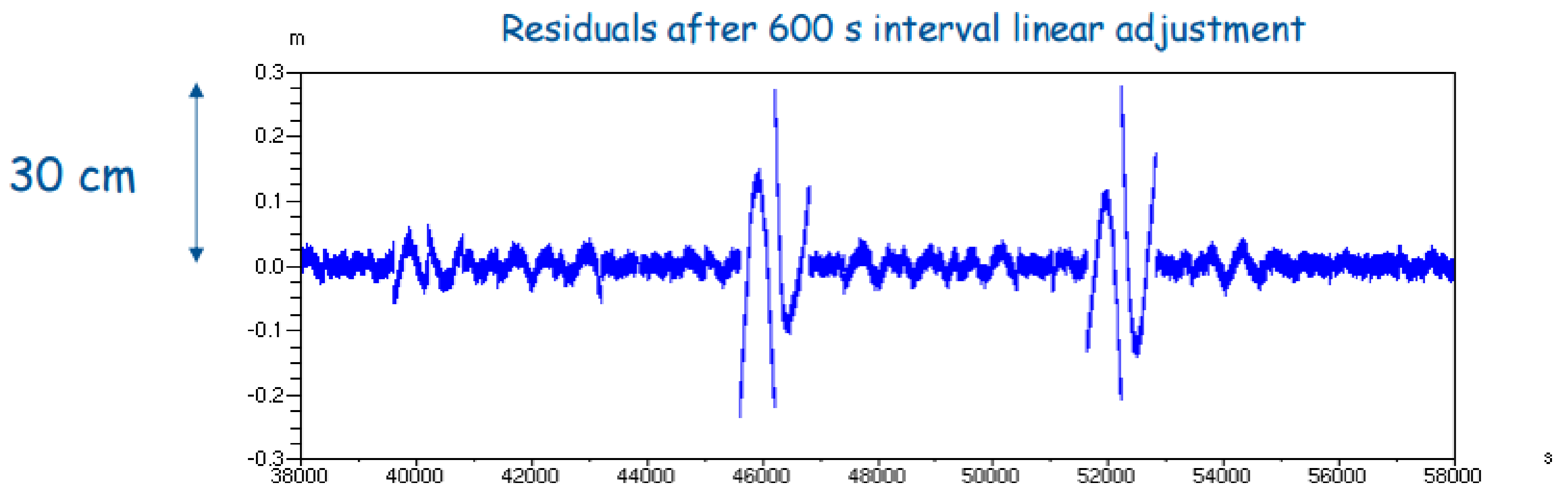
GPS clocks (s) without N order polynomial



Days in year 2016

GPS CLOCK : SAA IMPACT



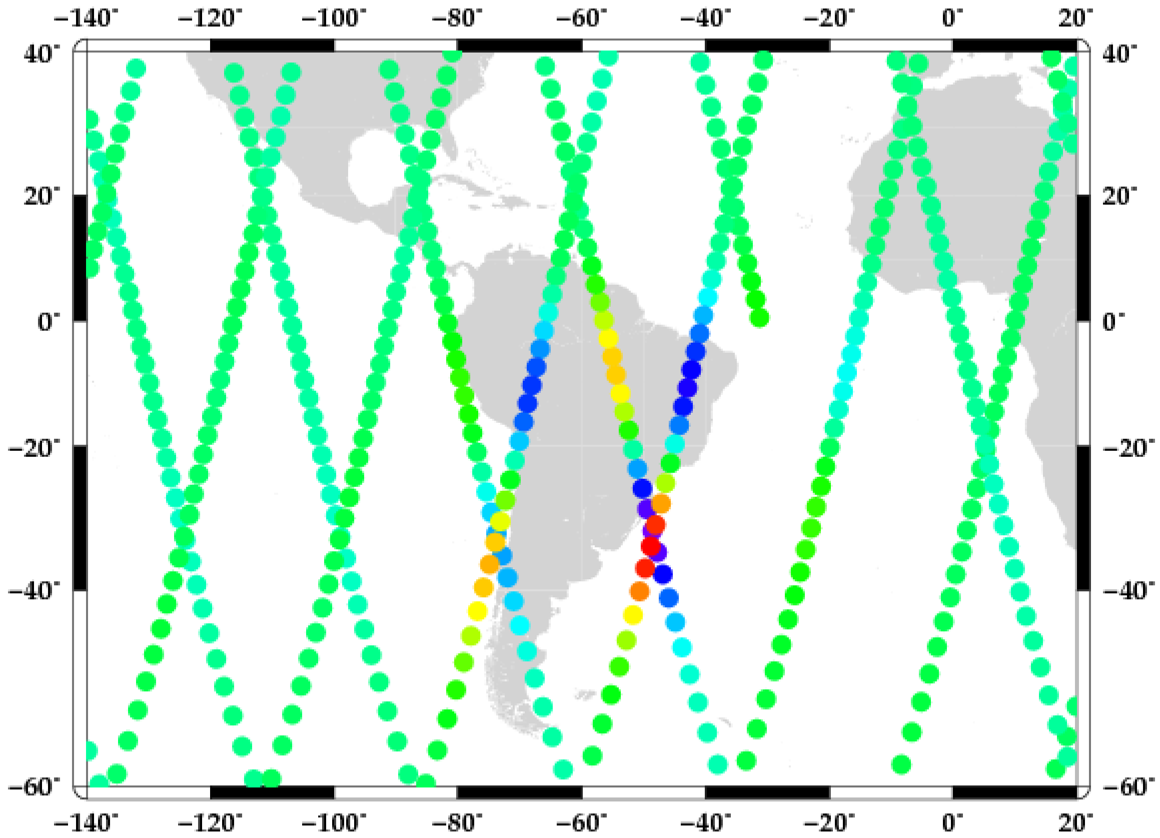


Important parabolic signatures are remaining (~ 30 cm on one pass)

see F. Mercier presentation, IDS AWG, May 2016

GPS CLOCK : SAA IMPACT

Geographic position of the anomalies



Estimation of the residuals curvature (600 s duration) normalized in [-1,1] → very clear SAA effect on the USO

see F. Mercier presentation, IDS AWG, May 2016

CORRECTION OF SAA EFFECT ON DORIS PHASE MEASUREMENTS (1/4)

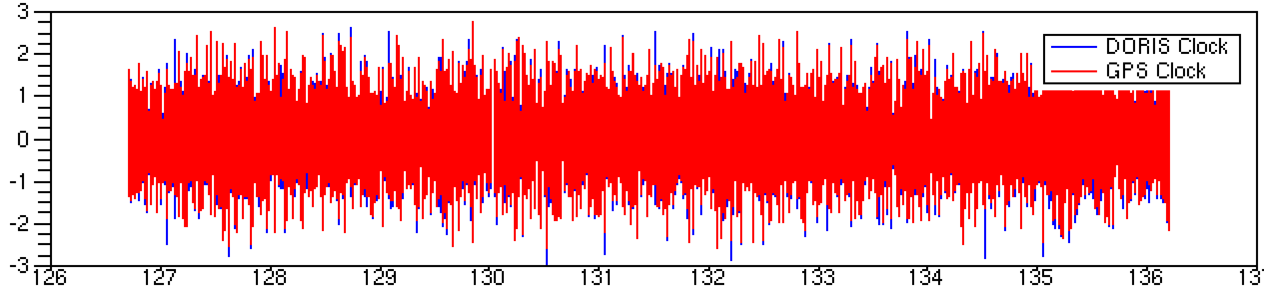
- DORIS computation : need of an on board clock model
- Traditionnaly : use of a 3rd degree polynomial identified using pseudo range only, over 9 days, on time beacons
- In the next slides : use of the GPS clock instead (interpolated on DORIS measurements epochs)
  (OUS observed using GPS measurement)
- Observed impact on Doppler phase residuals and phase residuals

Doppler phase residuals = Increment of phase measurements, on the ionosphere-free combinaison frequency

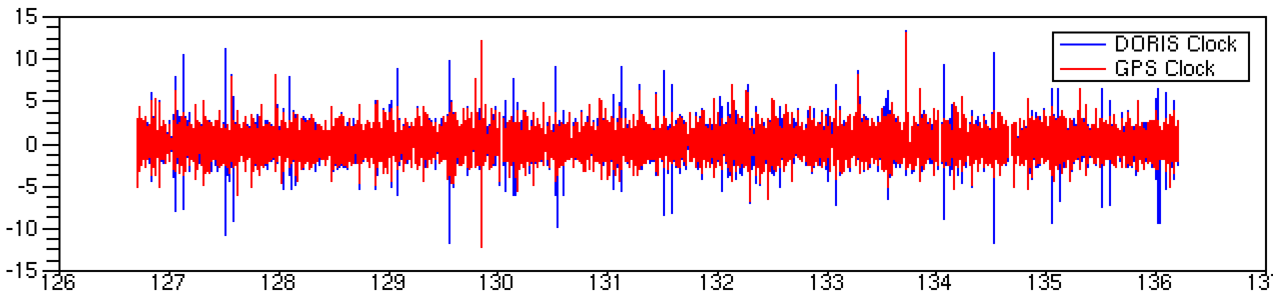
CORRECTION OF SAA EFFECT ON DORIS PHASE MEASUREMENTS (2/4)

GPS clocks (ns) without 4th order polynomial, with relativistic correction

DORIS ionosphere-free doppler phase residuals (cm)



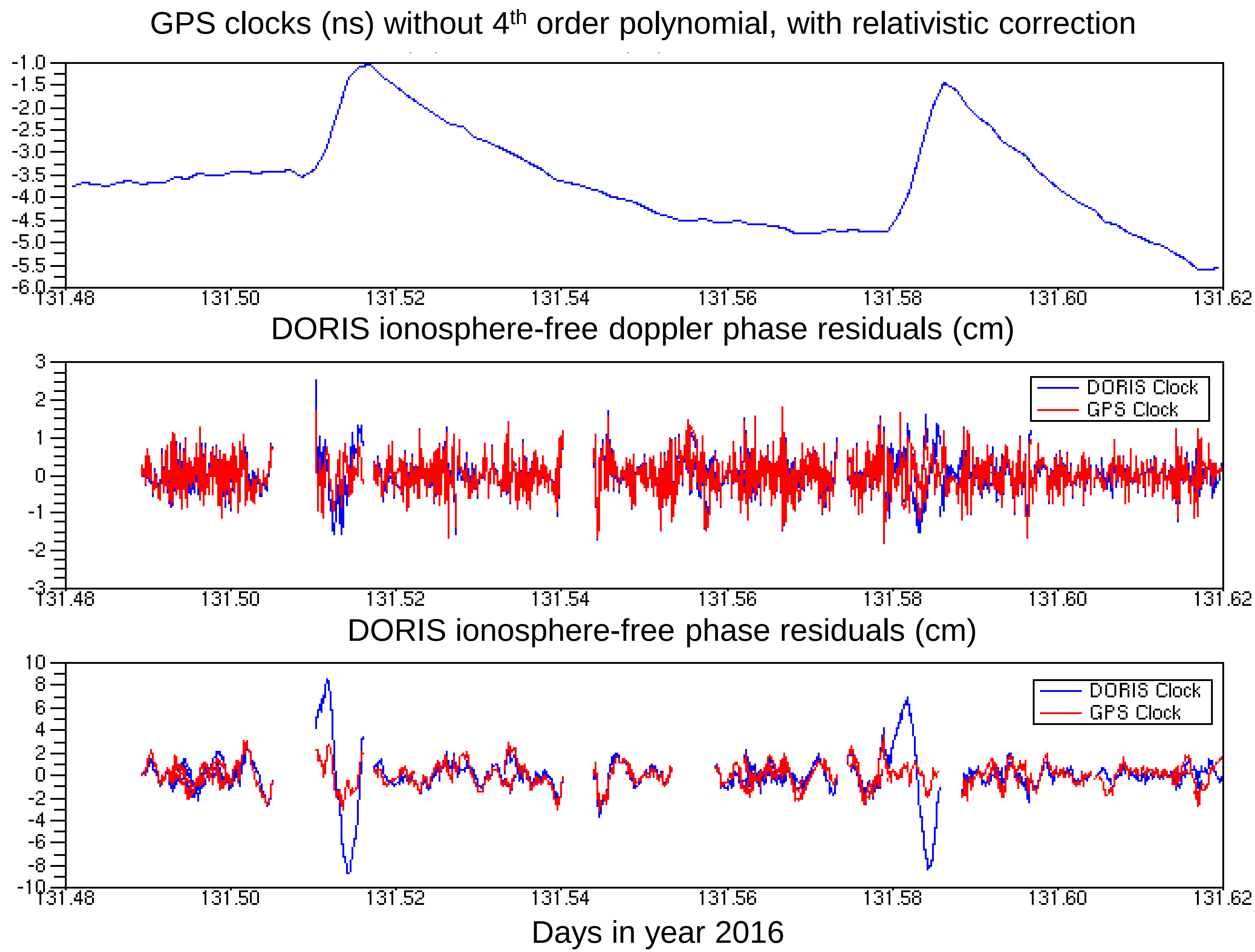
DORIS ionosphere-free phase residuals (cm)



Days in year 2016

Doppler phase residuals = Increment of phase measurements, on the ionosphere-free combinaison frequency

CORRECTION OF SAA EFFECT ON DORIS PHASE MEASUREMENTS (3/4)



Doppler phase residuals = Increment of phase measurements, on the ionosphere-free combinaison frequency

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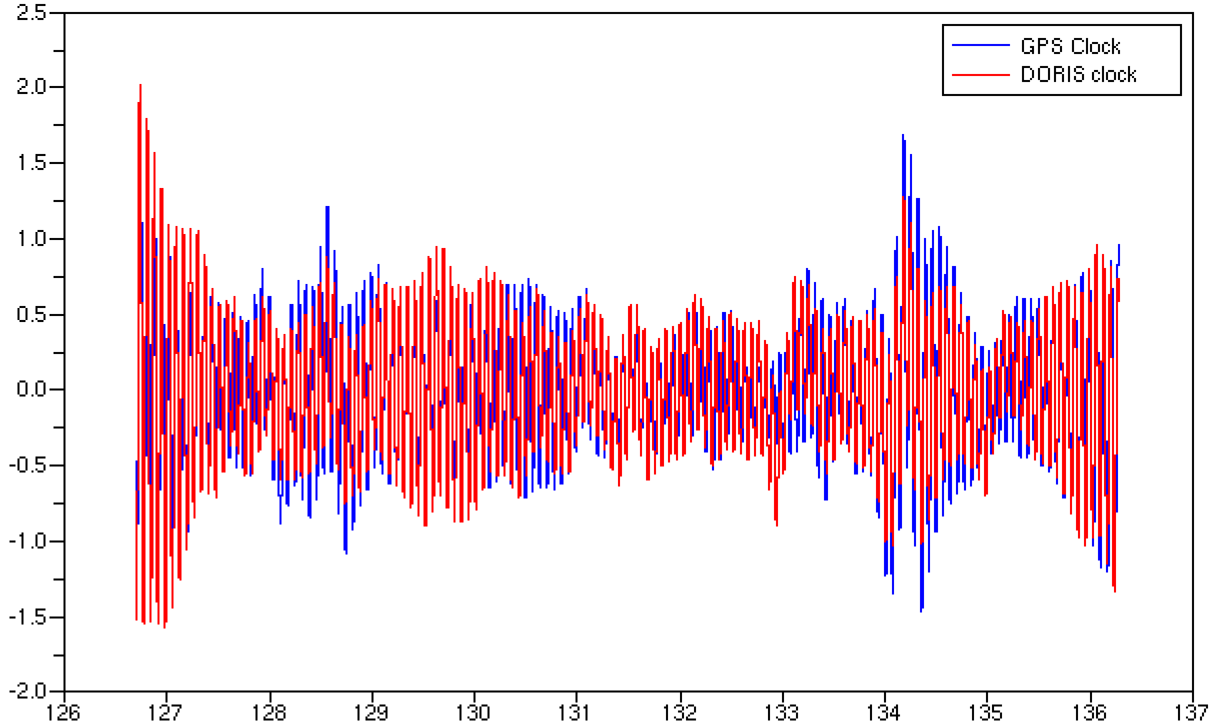
CORRECTION OF SAA EFFECT ON DORIS PHASE MEASUREMENTS (4/4)

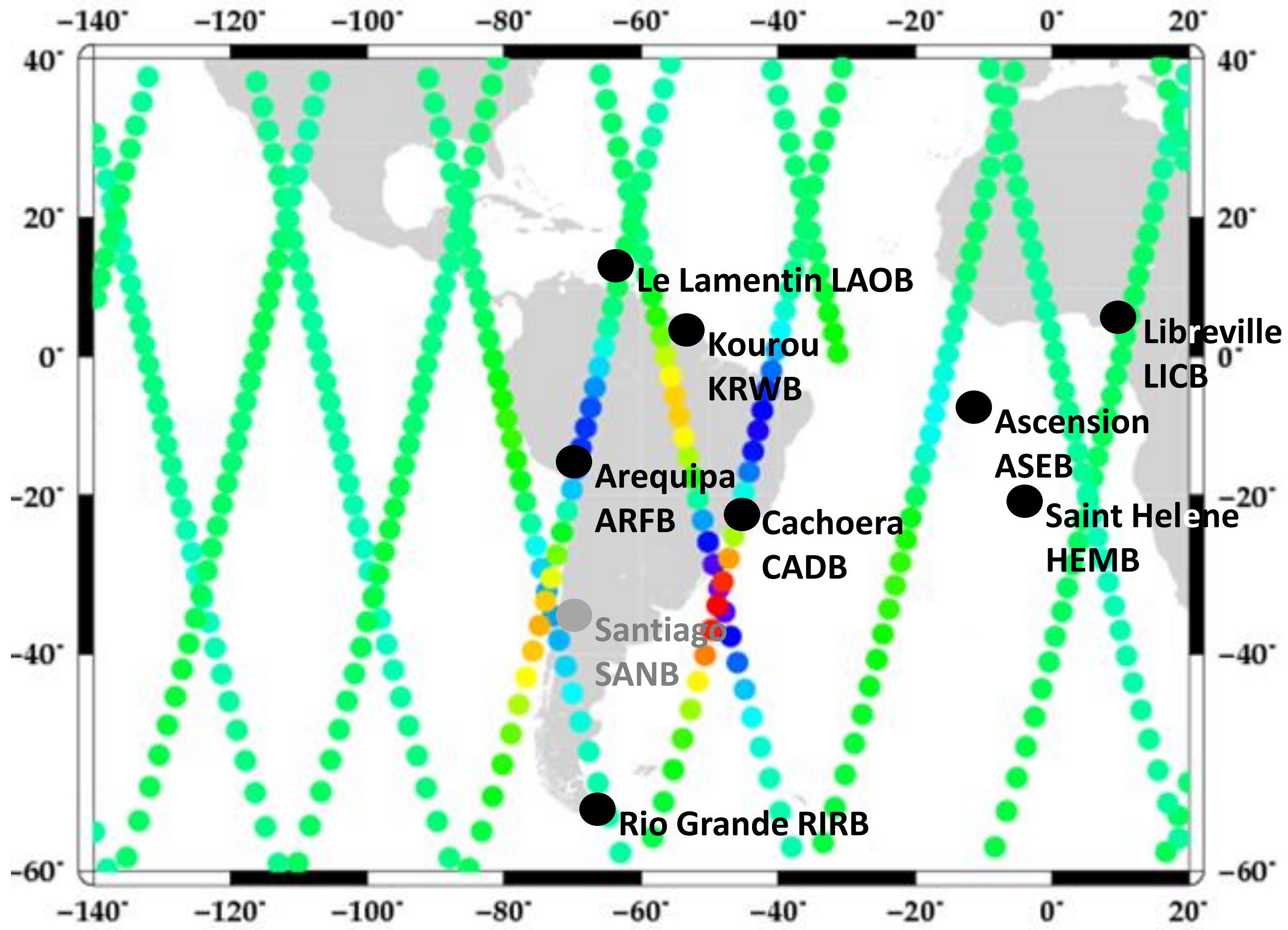
Radial orbit difference to GPS orbit (cm)



Days in year 2016

No impact on orbit

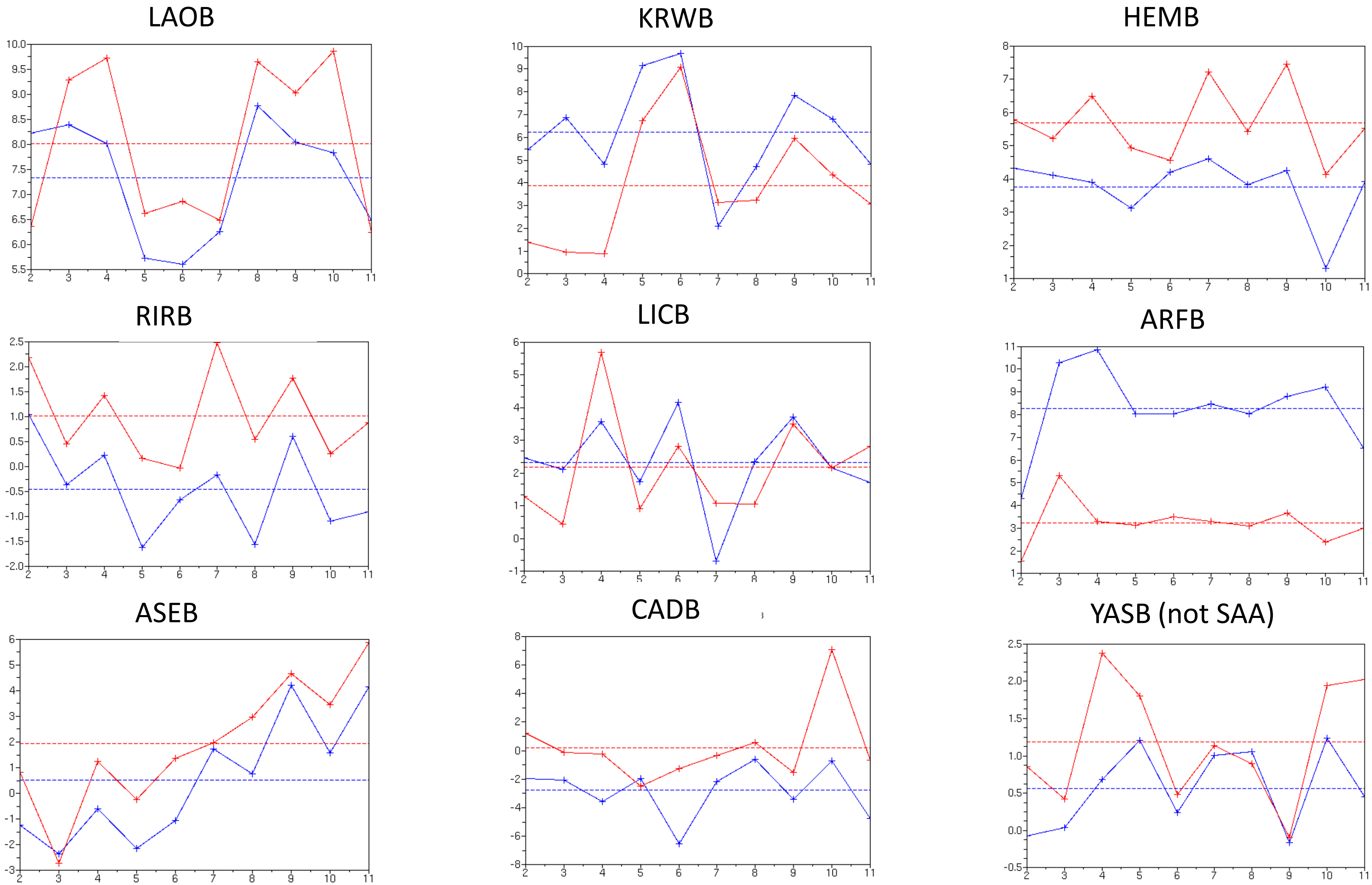
IMPACT ON STATION POSITIONING (1/2)



see F. Mercier presentation, IDS AWG, May 2016

IMPACT ON STATION POSITIONING (2/2)

Vertical position (cm) DORIS clock GPS clock



- Depends on station (Non-SAA station YASB for comparison)

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CONCLUSIONS

- OUS frequency can be observed using GPS measurements

→ DORIS time tagging precision can be evaluated

- SAA degradation visible on the GPS clock

- SAA degradation not easily observed on Doppler phase residuals (when zoomed in, « V » shaped residuals)

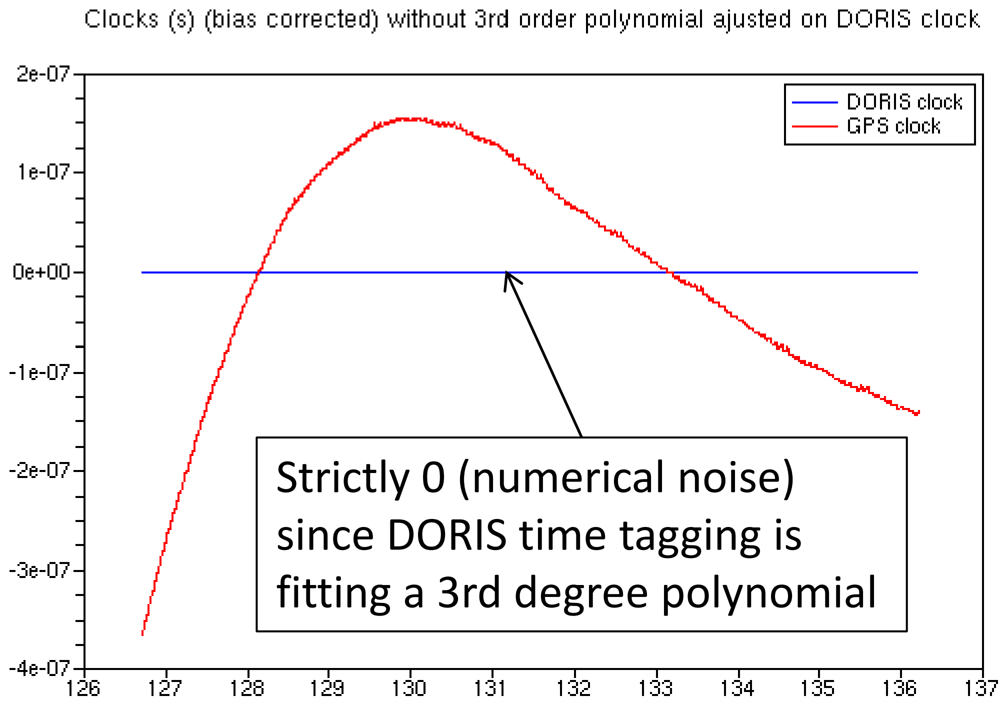
- But SAA degradation very easily spotted on phase residuals (large signature up to 8 cm, instead of 2-3 cm)

- Using GPS clock in DORIS computation enables to correct degradations. Sentinel3A : no impact on orbit

- Vertical station positionning : not significant impact

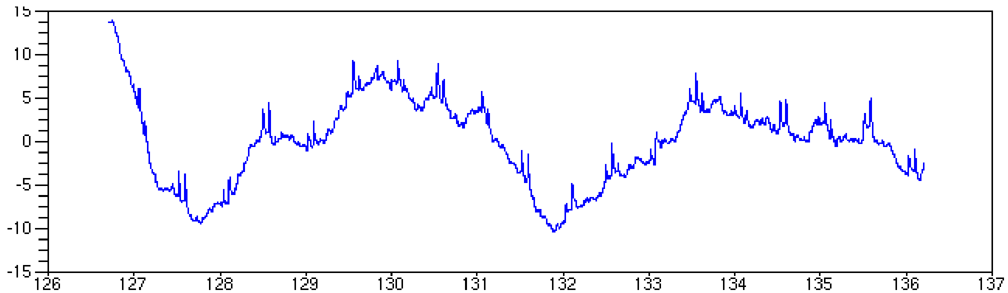
BACK UP SLIDES

DORIS TIME TAGGING

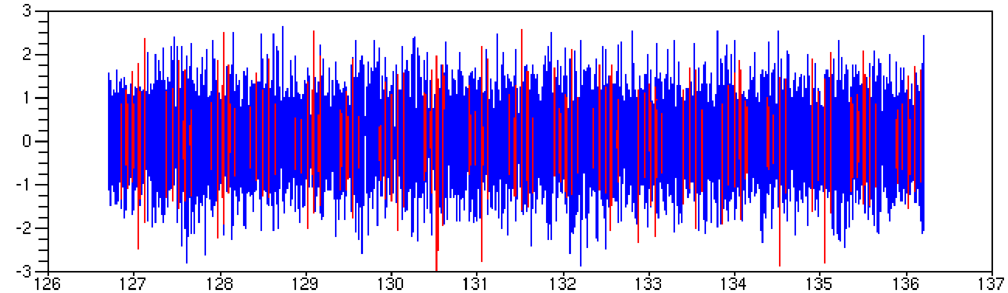


CORRECTION OF SAA EFFECT ON DORIS PHASE MEASUREMENTS (4/5)

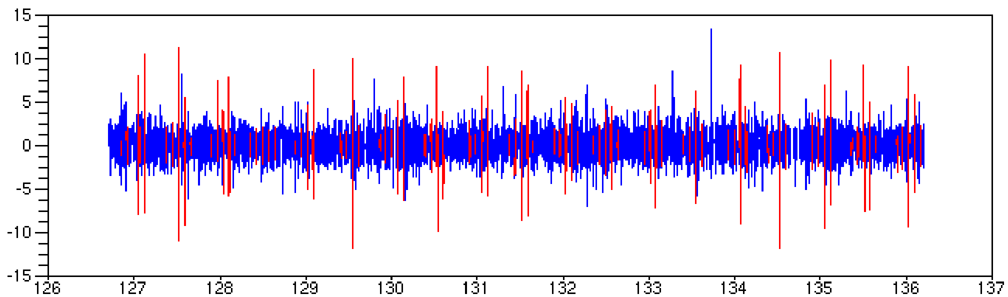
GPS clocks (ns) without 4th order polynomial, with relativistic correction



DORIS ionosphere-free doppler phase residuals (cm)



DORIS ionosphere-free phase residuals (cm)



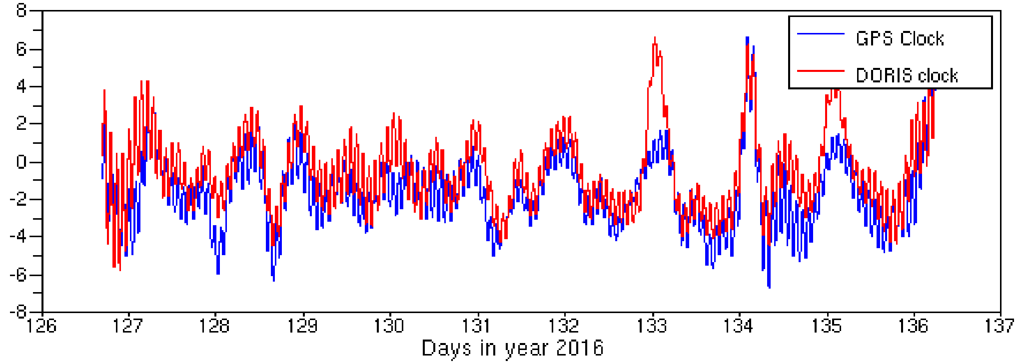
Days in year 2016

Most of the phase peaks are due to SAA stations

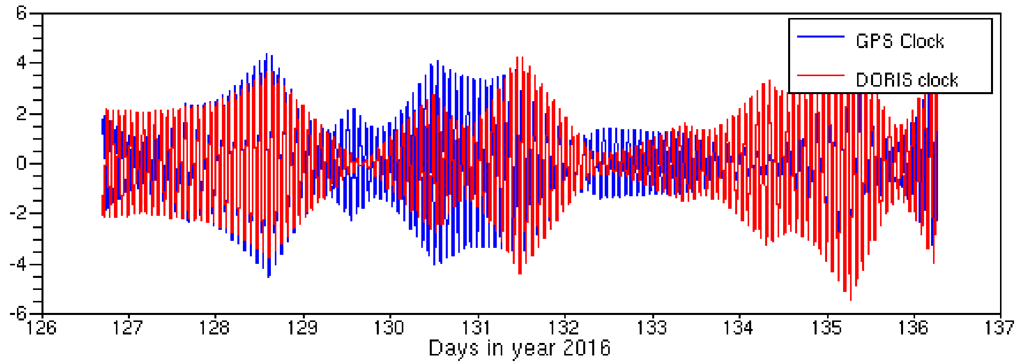
Non SAA stations
SAA stations

ORBIT DIFFERENCE

Along-track orbit difference to GPS orbit (cm)



Cross-track orbit difference to GPS orbit (cm)



Radial orbit difference to GPS orbit (cm)